cent. to 100 per cent., which can possibly be explained by some cause other than the combination of acid with water.

The contractions show that these points of discontinuity, though to some degree real, yet to another degree are ideal in that there is within the limits of 1 to 2 per cent. in the vicinity of such points a transition stage.

The values for μ are further expressed in terms both of Gladstone and Dale's, and of Lorentz' formula, and it is shown that the values in neither case are constant, but decrease with increase of concentration, and also that Pulfrich's formula which expresses the relation between the refractive index and the contraction in terms of a constant is only approximately applicable for results differing by small percentage concentrations, but not so in the case of considerable differences.

The results are illustrated by a selection of curves, with especial reference to the points of discontinuity.

'The Anatomy of Symmetrical Double Monstrosities in the Trout." By JAMES F. GEMMILL, M.A., M.D., Lecturer in Embryology and University Assistant in Anatomy, University of Glasgow. Communicated by Professor CLELAND, F.R.S. Received February 6,—Read March 7, 1901.

(Abstract.)

This paper contains the results of an investigation into the anatomy of a series of trout embryos exhibiting different degrees of symmetrical duplicity, and gives an account of the structural details which attend the fusion, disappearance, or special adaptation of parts in the region of transition from the double to the single condition. Some general questions suggested by these results are also discussed.

The monstrosities examined were four months old counting from the time of fertilisation, and they form a fairly complete series ranging from specimens in which the duplicity does not affect more than the anterior part of the head to specimens in which there is union by the posterior part of the body or by the yolk-sac only. The classification adopted has special reference to the material at my disposal and is on the same general lines as that given by Professor Windle in the 'Proceedings of the Zoological Society,' 1895.

The examination of the monstrosities was necessarily preceded by an investigation into the anatomy of normal trout embryos at corresponding stages in development. The results of this investigation are briefly given, special attention being paid to the cranial, visceral and vertebral skeleton, which at this period is wholly cartilaginous.

The following is a short summary of the anatomy of the various kinds of double monstrosity described :—

Type 1. *Union in head region—*

a. The twin brains united at the mesencephalon.
b. The twin brains united at the medulla oblongata.

Type 2. *Union in pectoral region—*

a. The pectoral fins absent on adjacent sides.
b. The pectoral fins present but united on adjacent sides.

Type 3. *Union behind the pectoral region—*

a. The twin bodies united at a considerable distance in front of the vent.
b. The twin bodies united close to the vent.

Type 4. *Union by the yolk-sac only.*

Type 1*a* shows the following characteristics :—

The cerebral lobes and the thalamencephala are doubled.

There are two infundibula, two hypophyses and two pairs of hypoaria. The optic lobes have a single cavity, but their basal parts show marked evidence of duplicity. Cerebellum pons and medulla are single, but there is a remarkable reappearance of duplicity in the cervical part of the spinal cord.

There are two pairs of 1st, 2nd, 3rd (and 4th) nerves, but only single pairs of the 5th, 6th, 7th, 8th, and vagus nerves are present. The cervical part of the spinal cord gives off in each segment a small extra pair of ventral roots.

There are two pairs of olfactory organs, all of which are normal. There are also two pairs of eyes, the outer ones (right of right head and left of left head) being normal. The inner or adjacent eyes (left of right head and right of left head) lie close to one another, and are more or less united. They have a common sclerotic and cornea, but the retinæ and choroids are separate. In some cases the lens is a single composite structure ; in others it is doubled. Of eye muscles the external recti are always, and the superior obliques are sometimes, awanting. The other eye muscles are all present, and each eye has its own optic nerve, choroidal fissure, choroidal gland and choroidal artery.

In front there are two sets of skeletal structures which converge rapidly as one goes backwards. The adjacent trabecular, supraorbital, and palatopterygoid bars coalesce posteriorly, while the adjacent parachordals are united along their whole length. There are two pituitary spaces. Only a vestige remains of the adjacent Meckelian cartilages. The notochords are double in front and remain separate for about twenty somites. They retain duplicity longer than any other structure. Adjacent neural and costal arch cartilages unite, become

reduced in size, and finally disappear as one goes backwards. The two outer series of cartilages are continued posteriorly into the single region of the body.

Head Kidney.—The glomerulus is sometimes double and sometimes single; when single it has two glomerular tufts, and is divided into three chambers. Each of the outer chambers gives origin to a normal Wolffian duct. The middle chamber is closed. When there are two glomeruli, a normal Wolffian duct arises from the outer half of each glomerulus, but the Wolffian ducts which should arise from the inner or adjacent sides of the glomeruli are either entirely absent or are represented only by short blind sacculated tubules.

Alimentary Canal.—Two mouth openings lead into a single buccal cavity. Pharynx, stomach, liver, and intestine are single, but there are two air-bladder diverticula.

Type 1*b*. *Union in Head Region, the brains being united at the medulla oblongata.*

The medulla and the fourth ventricle cavity bifurcate anteriorly and lead to two separate sets of mid- and fore-brain cavities and masses. Pons and cerebellum are double. There are two sets of cranial nerves. The inner or adjacent elements of the 5th, 7th, and 8th pairs are reduced in size, while the corresponding vagi are extremely rudimentary. The anterior part of the medulla is double; the posterior part is single and composite. The cervical part of the spinal cord shows striking evidence of original duplicity, and has a set of small extra roots coming off from its ventral aspect as in Type 1*a*.

There are two pairs of olfactory organs and two pairs of eyes, all of which are normal. The outer auditory organs (right of right head and left of left head) are normal. In addition there is a small malformed auditory organ placed in the angle between the two converging heads; it consists of united adjacent labyrinths and capsules, and has distributed to it on either side the small adjacent 8th nerves previously mentioned.

Cranial Skeleton.—In front, the cranial skeletal elements are in two separate sets; these converge posteriorly, their basal parts uniting at the level of the medulla oblongata. There are thus two separate nasal cartilages, two separate sets of trabeculæ cranii and two pituitary spaces. The adjacent parachordal cartilages unite and form with the outer ones a single plate which underlies the composite medulla oblongata and covers the cranial parts of the two notochords. The inner or adjacent palatopterygoids, supraorbitals, hyo-mandibulars and periotic capsules are united and reduced in size. In the visceral skeleton there are elements representing fused adjacent Meckelian and hyoid bars, while the copular cartilage which succeeds the glossohyal is

bifid anteriorly. The notochords remain separate for at least thirty somites, and have the same arrangement of neural and costal arch cartilages as was described in connection with Type 1*a*.

Heart, &c.—The heart chambers and the truncus arteriosus are single, and there are the usual number of gills and gill vessels. There are, however, two sets of carotid and hyoid arteries, the inner or adjacent pairs being derived directly from the truncus arteriosus. The truncus arteriosus arches dorsally in the septum between the two mouths to reach the base of the skull, and then divides into two limbs which are continued backwards to join the aortic collecting roots on either side. The dorsal aorta remains double so long as the notochord is double.

Head Kidney.—There is a large composite glomerulus containing two vascular tufts and divided into three compartments. Normal Wolffian ducts arise from the outer compartments, while the middle one gives origin to a coiled sacculated tubule which ends blindly in the tissue of the head kidney and represents united adjacent Wolffian ducts.

The *alimentary canal* has two mouth openings, two buccal cavities, and two air-bladder diverticula. Pharynx, œsophagus, stomach, liver, intestine, and vent are single.

Muscles.—In both (*a*) and (*b*), so long as the notochords are separate, there exists between and ventral to them a median muscular mass, divided into segments corresponding with the mesoblastic somites, innervated by the small extra ventral spinal roots previously mentioned, and representing united adjacent lateral muscles.

Type 2. *Union in Pectoral Region.*

(*a.*) *Adjacent Pectoral Fins absent.*
(*b.*) *Adjacent Pectoral Fins present, but united.*

In both cases the brains, the cranial and visceral skeletons, the organs of sense, and the upper parts of the spinal cords are completely doubled. There are two hearts and two trunci arteriosi. In (*a*) the auricles communicate, and the sinus venosus is a large common chamber receiving two sets of jugular veins, but receiving only a single pair of cardinals. In (*b*) the auricles are separate, the sinus venosi have only a narrow neck of communication, and there are two complete sets of jugular and cardinal veins. The inner or adjacent set of cardinals is, however, much reduced in size.

Pectoral Fins.—In (*a*) pectoral fins are entirely absent from the adjacent sides of the twin bodies; in (*b*) they are present in a more or less united condition, the union being greatest towards the posterior border.

The head kidney resembles that described for Type 1 (*b*); the median tubule is, however, larger, and is continued further backwards.

Alimentary Canal.—Mouth, pharynx, air bladder and stomach are double. Union takes place in the pyloric region. Liver, intestine and vent are single.

Type 3. *Union by Posterior Part of Body.*

The intestines are united for a greater or less distance forwards from the vent, which is almost always single. The sagittal planes of the twin bodies converge ventrally in a degree which, roughly speaking, varies directly as the degree of duplicity. The spinal cords may or may not unite anterior to the place of union of the notochords. In some cases the spinal cords remain separate along their whole length. As a rule, in cases where ventral convergence of the sagittal planes is well marked, dorsal structures, such as the spinal cords, dorsal fins, and dorsal edge membranes, remain double longer than structures which are more ventrally placed.

The twin head kidneys are quite separate, and each gives origin to two Wolffian ducts. The relations of the posterior parts of these ducts and of the bladders show remarkable variety. In rare cases the two adjacent Wolffian ducts (*i.e.*, left duct of right twin and right duct of left twin) end blindly and separately, while the two outer ducts open into a single normal bladder. In all other cases there are two bladders, each of which receives a right and a left Wolffian duct belonging to different twins. The two bladders may be quite separate, or they may communicate with one another. When they are separate each of them may open by a urinary pore, or one of them may have no outlet, and may be greatly enlarged through retention. When the bladders communicate with each other, only one of them possesses a urinary pore.

The intestines are separate in front, but in all my specimens they unite posteriorly. The united part usually ends by a single vent, but in one remarkable instance two vents were present which terminated by anal orifices situated on opposite sides of the composite body of the monstrosity.

Type 4. *Union by Yolk-sac only.*

Each embryo has a complete and separate complement of organs. The alimentary canals are shut off altogether from one another and from the yolk. The vitelline circulations are crossed.

General.

The general part of the paper discusses briefly—

(1.) The idiosyncrasies and general arrangement of mesial and paired organs at the transitional region in symmetrical double monstrosities.

(2.) Certain instances of correlation and irregularity in development. Mode of origin of double monstrosities in the trout.

The discussion under these heads is based on the evidence brought forward in the descriptive part of the paper.

(1.) It is shown that at the region of transition in laterally symmetrical double monstrosities the notochords are the last structures to unite, while equally primitive structures, both dorsal and ventral to the notochords, viz., the neural axis and the alimentary canal, lose their duplicity earlier. It is further shown that those parts of the neural axis and alimentary canal which are most closely apposed to the notochords retain evidence of original duplicity longer than parts which are more remote. The floor and roof of the neural axis and of the alimentary canal are seen to be in marked contrast in this respect.

Duplicity of the dorsal aorta, of the pronephric glomerulus, of the vertebral cartilages, of the body muscles and of various other structures is correlated with duplicity of the notochord.

In paired organs the transition from the double to the single condition takes place at the expense of the inner or adjacent elements, which are usually united and reduced in size before they disappear altogether. A list is given of the more important examples of union and reduction in size of adjacent elements in the transitional region, which are mentioned in the descriptive part of the paper.

From the evidence brought forward it is inferred that fusion has played a not unimportant part in moulding the form of the neural axis and the alimentary tract in the transition region. The union of adjacent paired structures is probably to be explained by the fusion of mesoblastic blastema developing laterally from each of the embryonic axes near the place of convergence and union.

(2.) The law that union takes place between homologous structures always holds good. Both twins usually contribute equally and symmetrically to the sum of structures in the transitional region. A short list of exceptions to this rule is tabulated, but their paucity and want of importance only serve to make more striking the general symmetry of structure in all the specimens examined.

With the rarest exceptions, all double monstrosities in the trout are examples either of anterior duplicity or of union by the yolk-sac only. This contrasts very markedly with the types of double monstrosity found in the higher vertebrates, particularly in the birds and mammals. An explanation is suggested which depends on the mode of origin of the primitive streak in osseous fishes and on the manner in which the blastoderm overgrows the yolk mass.